Renewable and Sustainable Energy Reviews 24 (2013) 198–208

Contents lists available at SciVerse ScienceDirect

Renewable and Sustainable Energy Reviews

journal homepage: www.elsevier.com/locate/rser

An overview of renewable energies in Iran

Mohsen Bahrami [a,b,*], Payam Abbaszadeh [a,b]

[a] Technology Foresight, Department of Management, Science and Technology, Amirkabir University of Technology (Tehran Polytechnic), Tehran, Iran
[b] Futures Studies Research Institute, Amirkabir University of Technology (Tehran Polytechnic), Tehran, Iran

A R T I C L E I N F O

Article history:
Received 6 May 2012
Received in revised form
12 March 2013
Accepted 15 March 2013
Available online 15 April 2013

Keywords:
Renewable energies
Iran
Power plant
Solar energy
Biomass and biogas
Fuel cell and hydrogen
Geothermal energy

A B S T R A C T

Iran as a major oil producing country has increasingly paid attention to the non-fossil energy resources, in particular to renewable energy sources for its longer term energy plans. In this regard, 11 projects pertaining to solar energy are being utilized or carried out by Iran's Ministry of Energy. The total photovoltaic power installed in 2004 was 14,020 MW. This rate reached 67 MW by the end of 2010. Further, two geothermal projects are being constructed in Ardabil Province at present. By the end of 2010, the Meshkinshahr geothermal power plant project revealed a progress rate equal to 50%. Similarly, the package construction project in Ardabil revealed a 32% progress. Due to financial hardship in the Fourth Development Program, the completion of these projects was extended to the end of the Fifth Development Program. The nameplate power of biogas power plants in Iran is 1.860 MW the total installed capacity is 1.665 MW. According to Strategy Document of Fuel Cell Technology Development (Approved by the government in 2004), Iran has revealed good progress in fuel cell projects. Private sectors have already signed contracts to build more than 600 MW of biomass systems and 500 MW of new wind energy developments. The nominal power of the wind parks that can be erected in the available sites with remarkable wind potential in Iran is approximately 6500 MW, employing wind turbines of 60,000 MW nominal power. The estimated mean annual capacity factor of these wind parks is 33%.

Contents

1. Introduction

Global energy consumption has increased two folds in last 40 years; see Fig. 1 from IEA Key World Energy Statistics [1]. In 1960, the global energy consumption rate was 3.3 Gtoe, while in 1990 this rate hit 8.8 Gtoe. This indicates an average annual growth of 3.3% and a total increase of 166%. Presently, the global energy consumption rate is 10 Gtoe/year and it is predicted that this rate would amount to 14 Gtoe/year by 2020 [2]. These rates indicate that the global energy consumption rate is on the rise in years to come. This has highlighted the important issue, whether fossil fuel energy resources can meet the global energy demand for survival and development in the coming decades? While the concern for pollution and global warming is overshadowing all planning and decision makings. Two major

* Corresponding author. Tel./fax: +98 21 66 48 33 45.
E-mail address: mbahrami@aut.ac.ir (M. Bahrami).

1364-0321/$ - see front matter
http://dx.doi.org/10.1016/j.rser.2013.03.043

reasons can be noted, that give rise to the development of alternative energy sources that are both clean and renewable:

(1) What is used a fossil fuel is concentrated chemical type, and nowadays is more valuable than being burn in for energy.
(2) The emergence of sustainable development concepts and issue, global warming, health problems due to pollution.

These and other issues have caused undertaking enormous effort by the global community to find alternative energy sources to control carbon dioxide emission, preserve the environment and get better value from fossil fuel sources.

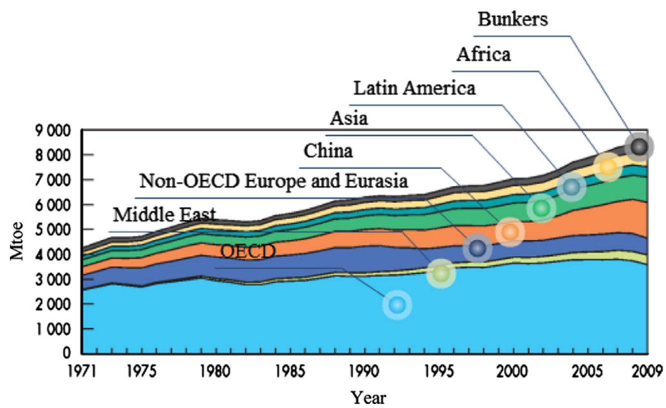


Fig. 1. World total final consumption from 1971 to 2009 [1].

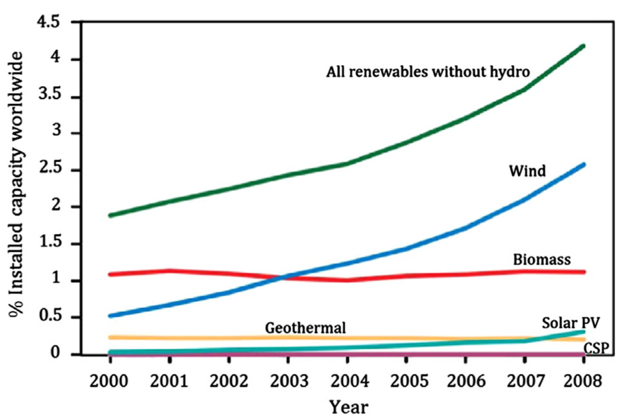


Fig. 2. Renewables as a percent of total installed capacity worldwide [3].

Alternative energy sources have been in the center of attention for many research and development activities in many different countries. In particular they are turning to renewables energies to meet their growing energy demands and have taken actions in the development and application of renewable energy technologies for sustainable development. As a percent of installed capacity, renewable energies increased by about 50% between 2000 and 2008 (see Fig. 2). The share of new renewables in global electricity production is also increasing [3]. Fig. 3 shows the global deployment potential of various renewable energy resources.

Future energy systems need to undergo drastic structural changes. In such systems, carbonless energy resources such as solar, wind, geothermal and neutral carbon like biomass energy play a more central role. Of course, various factors have slowed down and limited the spread and development of renewable energies in practice. These include initial and high operation cost; insufficient investment on localization and efficiency improvement of respective technologies and finally dearth of global, regional and local supportive policies. Nonetheless, researchers and industrialists have continuously made abundant strides to diminish, if not alleviate, these problems.

A variety of energy sources, whether nonrenewable or renewable, including wind power, solar, thermal, geothermal, photovoltaic, biomass, biogas, hydrogen and fuel cell are currently present in Iran. Fig. 4 illustrates electricity generation from nonrenewable and renewable sources in Iran.

If required investments for the development of power plants in Iran are made as planned from the relevant sources, the capacities of thermal, hydroelectric, nuclear and renewable power plants needed to meet demands in 2011–2014 will be according to Table 1. In Iran, most of the activities related to construction of environment-friendly pilot plants center around wind power, solar, geothermal and to some extend biomass and biogas energy sources. In following the status of each of these alternative energy sources is reviewed rather in detail.

2. Wind energy

To efficiently utilize alternative energy resources, it is necessary to acquire accurate identification of limitations, obstacles and available facilities. The degree to which Iran draws on current energy potentials and the development process of renewable

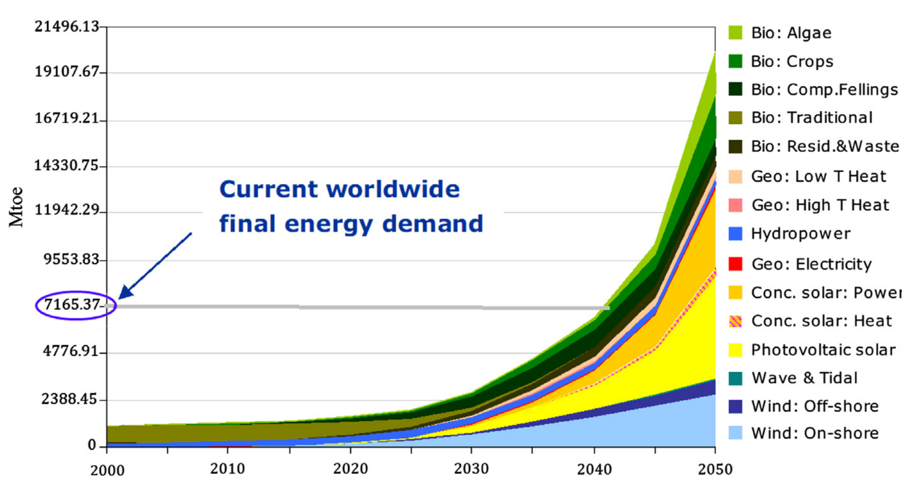


Fig. 3. Global deployment potential of various renewable energy sources [4].

energy carriers needs to be calculated and evaluated through a precise scientific method. Iran is one of the richest countries of the world in terms of various energy resources, since it enjoys extensive fossil fuel resources such as petroleum and natural gas and possesses high potential for renewable energies, wind power (Fig. 5).

Today, environmental and economic issues and attitudes have come under focus in different countries regarding exploitation of

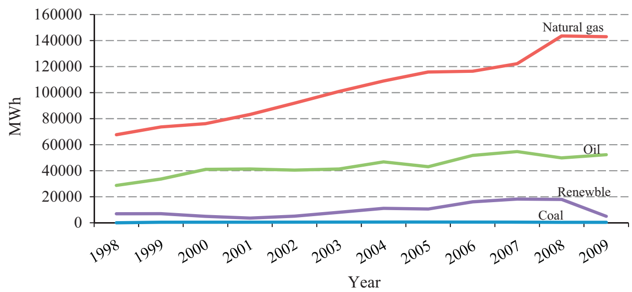


Fig. 4. Electricity generation from renewable and nonrenewable sources in Iran [5]. *Note*: Sources of electricity refer to the inputs used to generate electricity. Coal refers to all coal and brown coal, both primary (including hard coal and lignite-brown coal) and derived fuels (including patent fuel, coke oven coke, gas coke, coke oven gas, and blast furnace gas). Peat is also included in this category. Gas refers to natural gas but excludes natural gas liquids. Oil refers to crude oil and petroleum products. Electricity production from renewable sources includes hydropower, geothermal, solar, tides, wind, biomass, and biofuels.

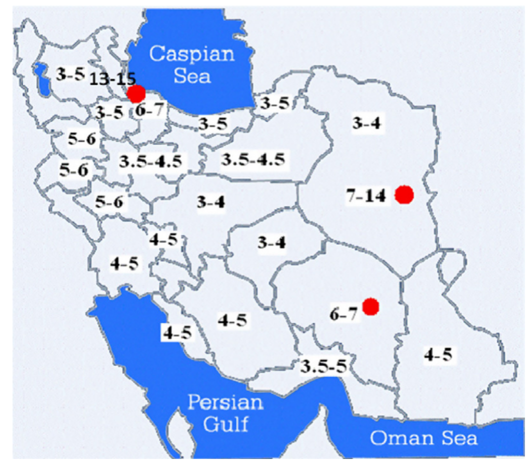


Fig. 6. Variation of wind speed potential in different site in m/s [15].

Table 1
The capacity of several power plants to meet demands in 2011–2014 [6].

Year	Thermal power		Gas	Combined cycle	Hydroelectric	Nuclear	Wind	Renewables
	Gas and liquid fuel	Coal						
2011	–	–	50	4116	753	1000	–	32
2012	–	–	100	5728	1500	–	100	67
2013	1290	–	–	5764	480	–	200	100
2014	1290	650	–	4145	785	–	200	6

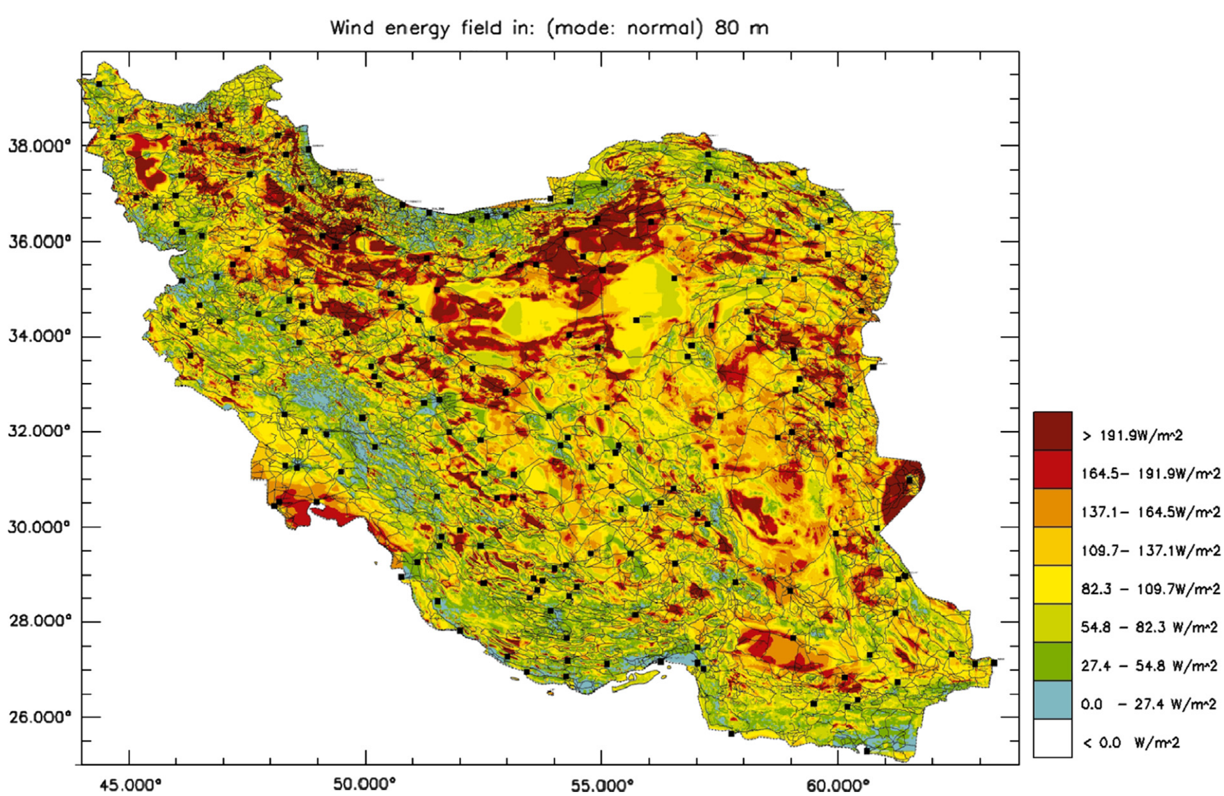


Fig. 5. Iran's wind capacity dispersion at an altitude of 80 m [13].

Table 2
Site Profile of wind turbines installed in Iran [11,12].

Wind power plant	Site	Province	Township	Installed Turbines	
				No.	MW
Manjil	Babaeian	Gilan	Rudbar	1	0.6
	Paskulan	Gilan	Rudbar	22	14.520
	Rudbar	Gilan	Rudbar	4	2.150
	Siahpush	Gilan	Rudbar	26	17.160
	Manjil	Gilan	Rudbar	31	13.250
	Harzvil	Gilan	Rudbar	27	13.500
Binalud	Khorasan	Binalud	43	28.380	
Ventis(Dizbad)	Khorasan	Mashhad	2	0.260	
Sahand	Tabriz, Sahand University	East Azarbayjan	Tabriz	1	0.01
Eynali	Tabriz	East Azarbayjan	Tabriz	3	0.66
Lutak	Zabol	Sistan and Baluchestan	Zabol	1	0.66
Babakoohi shiraz	Babakoohi	Fars	Shiraz	1	0.66
Mahshahr Khuzestan	Mahshahr	Khuzestan	Mahshahr	1	0.66
Total	–	–	–	**163**	**92.470**

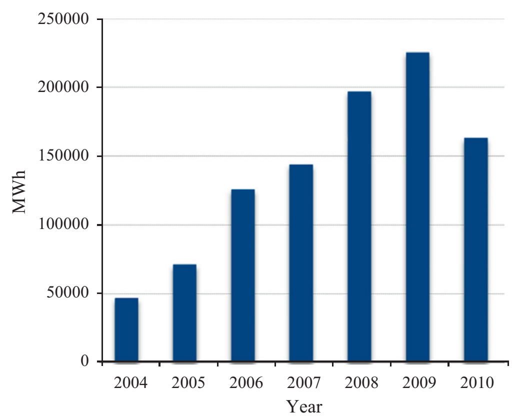


Fig. 7. Electricity generation from wind power plants.

Table 3
Electricity generation from several wind power plants [11,14].

Year	State	Nominal power (MW)	No. of turbines	Gross electricity generation (MWh)
2004	Gilan and Khorasan	24.88	56	46,511.471
2005	Gilan and Khorasan	44.58	92	70,902.196
2006	Gilan, Khorasan and Tabriz	58.81	110	125,313.646
2007	Gilan, Manjil	45.34	87	118,715.637
	Khorasan, Binalud	28.38	43	24,639.045
	Khorasan, Ventis[a]	0.26	2	NA
	Sahand Tabriz	0.01	1	NA
	Total	**73.99**	**133**	**143,354.683**
2008	Gilan, Manjil	61.18	111	139,838.980
	Khorasan, Binalud	28.38	43	56,472.212
	Khorasan, Ventis[b]	0.26	2	–
	Sahand Tabriz	0.01	1	NA
	Total	**89.83**	**157**	**196,311.192**
2009	Gilan, Manjil	60.58	110	170,209.282
	Khorasan, Binalud	28.38	43	53,803.593
	Sahand Tabriz	0.01	1	NA
	Eynali Tabriz	0.66	1	100
	Lutak Zabol	0.66	1	498.355
	Total	**90.29**	**156**	**224,611.230**
2010	Gilan, Manjil	60.58	110	109,665.050
	Khorasan, Binalud	28.38	43	50,557.633
	Sahand Tabriz	0.01	1	NA
	Eynali Tabriz	1.98	3	1179.891
	Lutak Zabol	0.66	1	1055.339
	Babakoohi Shiraz	0.66	1	93
	Mahshahr Khuzestan	0.66	1	44.587
	Total	**92.93**	**160**	**162,595.500**

[a] The number is negligible.
[b] It is a research project and it is not connected to the national electricity grid due to low level of generation.

energy resources. Many countries have shown much interest towards exploitation of renewable energy resources. Accordingly, application of wind power energy is continuously on increase in many countries. According to the latest official data [7], the global wind power capacity increased by 37.4 GW during 2009. According to US DoE [8], use of renewable energies, in general, and wind energy, in particular, is on the rise for the following reasons:

- Wind energy is economically competitive.
- Wind energy is a valuable future crop for farmers and ranchers (wind farm development is an excellent source of local jobs, from construction to maintenance and upkeep [9]).
- Unlike most other electricity generation sources, wind turbines do not consume conventional power sources and do not emit gases in the atmosphere.
- Wind energy is an indigenous, homegrown energy source that contributes to national security.
- The impacts of wind parks on the natural environment and human activities are mild [10].
- Because wind energy's “fuel” is free, it reduces the risk associated with volatile fossil fuels.

Iran has been involved in Designing and manufacturing of windmills since 2000 BC Vast windy regions are available in different parts of the country. Presently, there are good grounds in the country to expand utilization of windmills. Wind electricity generators can function as suitable substitutes for gas and steam power generating plants. Studies already conducted on wind energy potential estimation in Iran have indicated that at least 26 regions throughout the country fit the requirements for construction of such wind power generators. In all, 45 suitable sites have already been constructed in these regions. The nominal power of the wind parks that can be erected in the available sites with remarkable wind potential in Iran is approximately 6500 MW, employing wind turbines of 60,000 MW nominal power. The estimated mean annual capacity factor of these wind parks is 33%. Variation of wind speed potential in different sites is represented in Fig. 6. As indicated in Table 2, total of 92.470 MW power has been produced by 163 wind turbines. The greatest number of wind power turbines in Iran has been installed in

Manjil, a city in Guilan Province with 61180 MW annually. Electricity generation from wind power plants is indicated in Fig. 7 and Table 3. Iran's Renewable Energy Organization has already planned to set up wind farm turbines with a capacity to generate 1650 MW by March 2014.

3. Solar energy

The amount of energy the sun radiates in one second is more than that used by the whole world population since the beginning of history [16]. Fossil fuel resources are finite and give way to unwelcome climate changes, while solar energy is deemed as one of the cleanest types of energy, which can be used as a substitute to fossil fuel energy resources and can slow down global warming. These have provided suitable grounds for attraction towards solar energy especially in regions with high solar radiation. Solar energy technologies include solar heating, solar photovoltaic, solar thermal electricity and solar architecture, which can make considerable contributions to solving some of the most urgent problems the world is now facing [17].

Southwestern United States, Mediterranean countries, the Middle East and the Near East, Iran and deserts of India, Pakistan, China, and Australia can be pointed out among the regions with solar energy potential. In many parts of the world, there is the possibility of producing between 100 and 300 GWh of solar electricity using solar heating technologies in an area of one square kilometer. This rate is equal to the amount of electricity generated annually, in average load, by conventional fossil fuel, coal or gas power plants having a capacity of 50 MW.

Located on the world's Sun Belt, Iran enjoys 2800 sunny hours per year and its average solar insulation rate is estimated to be 2000 kWh/m^2 year (Fig. 8) [18]. Nearly 80% of the solar power plant in Shiraz, the first in Iran and the largest in the Middle East, has been built by local Iranian experts (Fig. 9). According to Iran's Renewable Energy Organization, Shiraz solar power plant will be operational by the end of the Fifth Five-Year Development Plan (2010–2015). There are currently 11 solar energy projects being utilized or carried out by the Ministry of Energy (Table 4). The total photovoltaic power installed in 2004 was 14.02 MW. This rate reached 67 MW by the end of 2010 (Table 5).



Fig. 9. Solar power plant in the southern Iranian city of Shiraz.

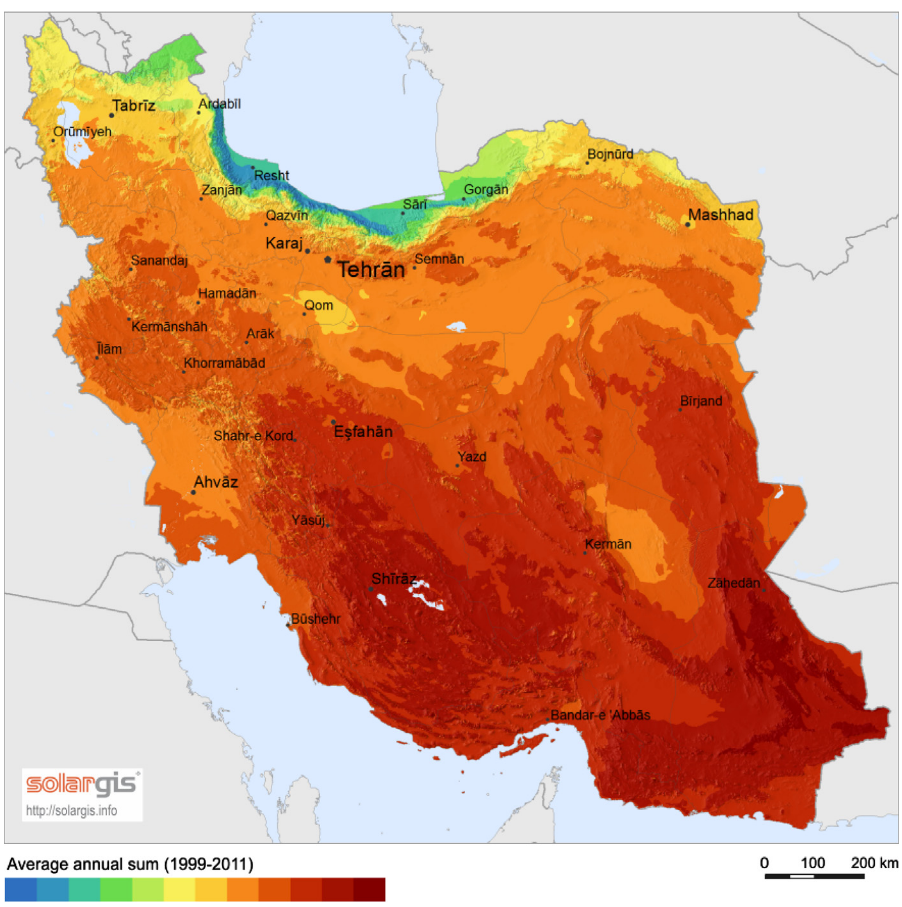


Fig. 8. Iran solar energy map [19].

Table 4
Specification of solar energy projects of Iran [6,11,14].

Project name	Region (Province)	Start	Utilize	Percentage of progress until 2010	Capacity (MW)	Lifespan (year)	Grid type
Darbid Yazd Power plant development	Yazd	1999	2000	100	0.012	25	Off-grid
SarKavir Semnan Power plant development	Semnan	1999	2000	100	0.015	25	On-grid
30 kW	Tehran, Taleghan	2000	2002	100	0.03	25	On-grid
Solar water heater[a]	Yazd, Khorasan, Sistan and Isfahan	2000	2002	100	4.312	20	-
Rural electrification to 60 households[b]	-	2006	2007	100	0.05	20	Off-grid
6 kW hybrid(Wind and solar)[c]	Tehran, Energy deputy affairs building	2006	2008	100	0.006	15	Off-grid
10 kW photovoltaic[c]	Tehran, Taleghan	2004	2008	100	0.01	25	Off-grid
Shiraz solar plant (Vapor phase)	Fars	1999	2008	100	0.25	20	Off-grid
Solar park(Purchase, build and install equipment for solar thermal research)	Alborz, Taleghan	2005	2009	100	–	20	Off-grid
Rural electrification to 634 households[d]	All of the country	2008	2010	31	0.65		Off-grid

[a] It is noteworthy that no activity has occurred regarding sunbath and solar water heater in 2010.
[b] The rural lacking electricity has been electrified in Khuzestan, Fars, Ardabil, Lorestan and Mazandaran provinces in 2010.
[c] At present, electrification is performed in package form and the generation numbers are not available, since no counters are installed.
[d] The project of electrifying 634 rural households will be carried out in two stages. The first stage covers 300 households and the second stage includes 324 households. Also, surveying the regions for the benefit of new rural is scheduled.

Table 5
Electricity generation from solar power plants in Iran [11,12].

Year	6 kW hybrid (Wind and solar) MWh[a]	30 kW photovoltaic (MWh)	Power plant (MWh)	Power plant (MWh)	Solar Tabriz	Total (MWh)
			Darbid Yazd	SarKavir Semnan		
2004	3	45	8.9	83.3	–	140.2
2005	–	10[b]	18	25[b]	–	53
2006	–	42	17	20	–	79
2007	–	32	15	24	–	71
2008	–	35	19	21	–	75
2009	–	31	15	21	5	72
2010	–	32	17	18	–	67

Since electrification has been performed in package form through the Tehran 10-kilowatt photovoltaic project and no counter is installed to record the numbers generated, it has not been mentioned in this paper.

[a] Due to changes old equipment and modifications in the power plant.
[b] Due to test and repairs, a portion of generated power is not recorded.

4. Geothermal energy

As a part of Alpine-Himalayan organic belt, Iran's plateau is principally divided into five major geological units based on remarkable tectonic history, magmatic events or sedimentary features (Fig. 10). These units are (i) Zagros, (ii) Sanandaj-Sirjan, (iii) Central Iran, (iv) East and South East zones and (v) Alborz and each major unit is subdivided into a number of sub-units with specific characteristics.

Based on the studies conducted through well logging in Iran, 14 apt regions have already been specified as indicated in Fig. 11. Only in one apt region, a capacity of 250 MW of electricity has been attained by digging three wells. Results indicate that Iran has substantial geothermal potential in Northern provinces and there are several hot water springs, the temperature of some of which reaches 85 °C. The ENEL Company suggests that Sabalan (Booshli), Sahand, Damavand, Maku-Khoy and Sareyn regions have promising prospects for electrical generation (Table 6) [21]. At present, two geothermal projects are being constructed in Ardabil province. The Meshkinshahr geothermal power plant project has already had a 50% progress, and the progress rate of package construction project in Ardabil has been 32% by the end of 2010 (Table 7). The construction of these two projects started in 2005. Due to budget problems, the length of these two projects was extended to the end of the Fifth Plan.

5. Biomass and biogas

At the moment, useful and applicable resources of biomass are not limited to wood and dried leaf only and encompass a wide range of materials such as solid and fluid urban waste, industrial waste, etc.

Renewable resources of energy are the fourth largest energy resource in the world, after coal, petroleum and natural gas. This resource supplies almost 14% of the global primary energy and presently more than 11.5% of global primary energy is supplied through biomass resources. This is while 3 to 4% of the required primary energy is merely supplied by biomass resources from the United States. The amount of interest in using biomass as an energy source has increased—it is estimated to comprise 15–50% of the world primary energy by 2050 [23]. Biomass capability is not limited to heat production. In fact, it is also used in production of coldness and required fuels for transportation and electrical energy generation. Nearly 4000 MW of power generation and 225,000 MW of heat production in modern power plants was fulfilled in 2005 using biomass resources, of which 10,000 MW was generated in the United States (almost 58% of generation market of renewable resources in the United States). Also, more than 50 billion liters of renewable fuel is produced and consumed from biomass resources.

Based on the studies conducted, almost 64% of primary resources of new energies in the EU is designated to biomass resources. Similarly, around 9% of the generated electrical energy and 98% of the thermal energy, produced by new energy resources, belongs to biomass energy resources (including hydroelectric resources). Biomass energy is the sole renewable energy source which delivers energy in the form of electricity, heat, coldness, and automobile fuel and in solid, liquid and gaseous forms. Furthermore, bio matters which replace petrochemical feeds are also among its other products.

Fig. 12 illustrates share of biomass waste potential energy in Iran. The nameplate capacity of biogas power plants in Iran is 1860 KW, the total installed capacity is 1665 kW and the total Gross generation is 5967 GWh. According to potential evaluations conducted, installable capacity at the urban solid waste disposal site of Shiraz equals 1060 KW. However, considering the position

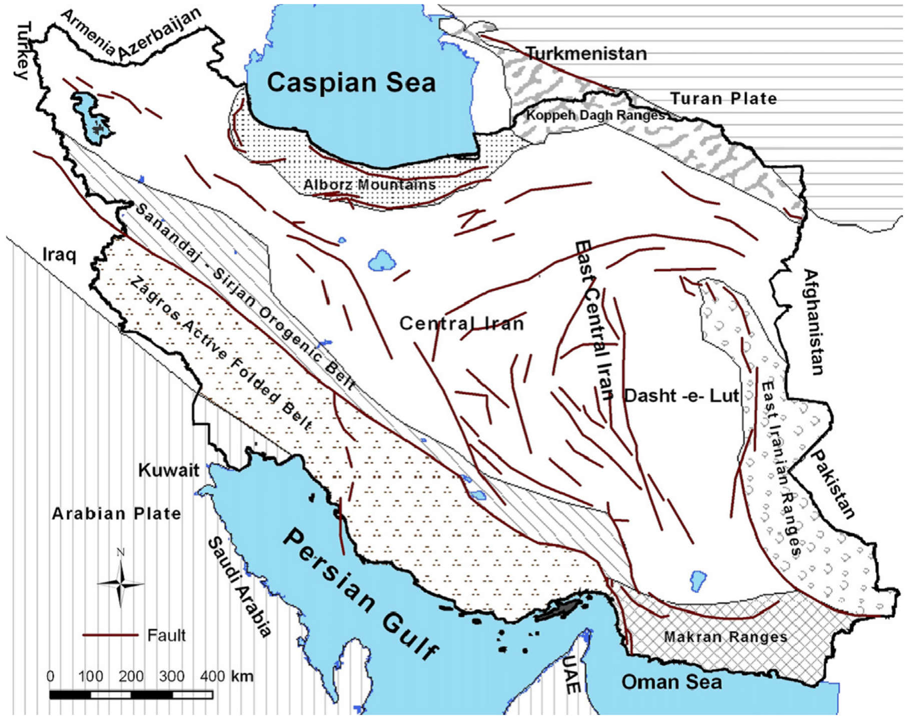


Fig. 10. Main structural (tectonic) regions of Iran [20].

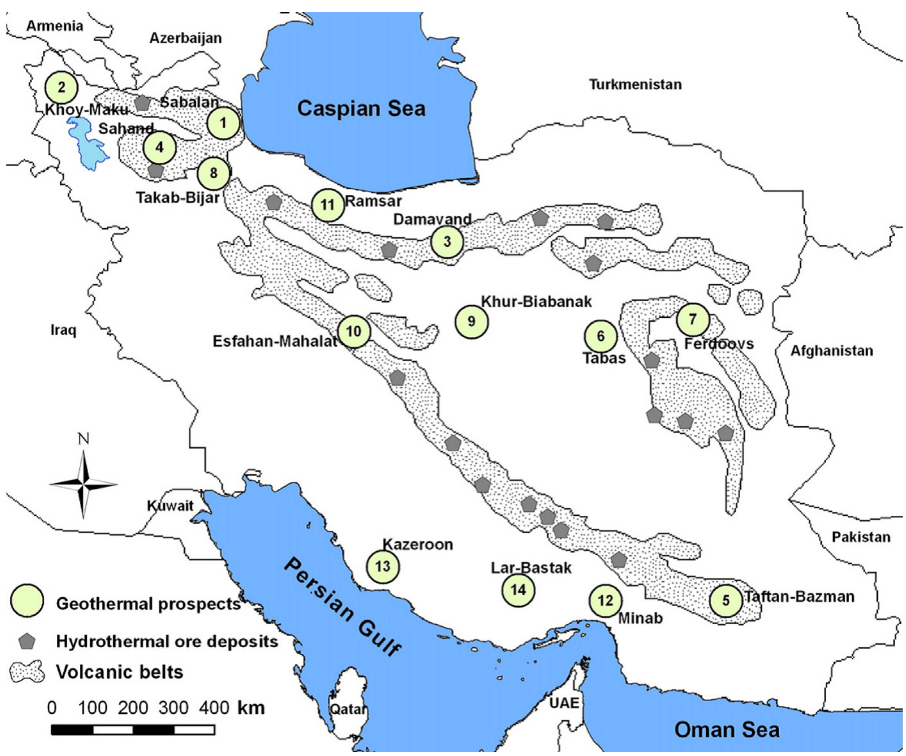


Fig. 11. Geothermal energy resources map of Iran. The 14 geothermal areas are ranked in order of importance [20] (Sabalan the highest rank and Lar-Bastak the lowest).

and specifications of waste disposal, during past years, the current utilization capacity of the disposal site of Shiraz is 450 KW. With regard to the equipment installed, the real rate of electrical energy production from the solid waste disposal site of Mashhad is approximately 654 MWh per month. Of course, the obtainable rate of energy will considerably be higher if disposal site is constructed and complete equipment is installed. Table 8 shows specifications of biomass and biogas projects of Iran's Ministry of Energy. Table 9 shows Iran's production capacity and domestic consumption rate of electricity from biogas power plants.

6. Fuel cell and hydrogen

Limitation of fossil fuel sources, their negative environmental effects, use of hydrocarbon resources, inflation in fossil fuel prices,

Table 6
Different potentially geothermal regions investigated north and north-west Iran [22].

S. no.	Region	Estimated thermal energy (J)	Estimated mean r eservoir temperature (C)	Reservoir depth (m)	Region area (Km^2)
1	Meshkinshahr	14.84×10^{18}	240	2000–3000	500
2	Sabalan (Booshli)	16.48×10^{18}	240	1500–2500	550
3	Sareyn	16.65×10^{18}	140	500–1000	550
4	Damavand	5.11×10^{18}	190	2000–3000	550
5	Sahand	7.6×10^{18}	160	1500–2500	11,000
6	Khoy-Maku	30.40×10^{18}	170	2000–3000	6200

Table 7
Specification of geothermal energy projects of Ministry Energy of Iran [6].

Project name	Province	Start	Utilize	Percentage of progress until 2010	Capacity of project(MW)	Annual energy production capability(GWh)	Grid type
Meshkinshahr geothermal power plant(Conduct exploration drilling, production and injection)	Ardabil	2005	2014	51	50	370	On-grid
Construction 3–5 MW package	Ardabil	2005	2014	32	3–5	40	On-grid

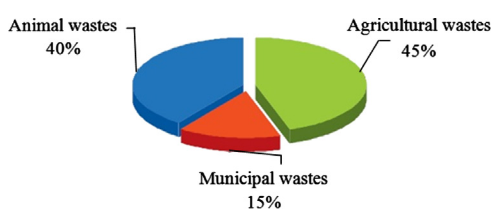


Fig. 12. Share of potential energy of biomass waste in Iran [25].

political disputes and their impacts on supplying sustainable energy are among reasons instigating politicians as well as energy and environment experts to move toward development of a modern and secure energy supplying structure that is efficient and environment friendly. In such a system, hydrogen can be one of the best options to play the role of energy carrier.

Hydrogen—the most abundant element available on Earth surface could be produced by various methods. It is estimated that 90% of the visible universe is composed of hydrogen [26]. In an ideal hydrogen-based energy system, hydrogen is produced from the generated electricity of renewable (i.e. wind, solar, geothermal, etc.) resources. After storage and transfer to consumption places, hydrogen will have diverse applications in areas like microelectronic equipment (milliwatts), transportation and power plant industries. According to this approach, many believe that the ultimate fuel for human will be hydrogen and that the human being will experience the hydrogen era in the near future.

Abundance, almost unique consumption, negligible pollutants diffusion, reversibility of its production cycle as well as reduction of greenhouse effects can be pointed out as features distinguishing hydrogen from other available fuel options. Hydrogen energy systems are permanent, sustainable, non-perishable, pervasive and renewable, since they are independent from primary energy resources. It is predicted that its production and consumption as an energy carrier will spread all over the world in near future and accordingly hydrogen economy will be stabilized. Nevertheless, it is axiomatic that hydrogen cannot compete, at the moment, with other energy carriers in terms of price. Hydrogen and fuel cells can have a central controlling role in urban pollution in the future. Transformation of available chemical energy in hydrogen to electrical energy is performed by fuel cell. Based on their application and structural features, fuel cells are divided into several types. The importance of fuel cell technology in a hydrogen-based energy system (hydrogen era) is such that many have equated it to the steam engine era development for trains. In addition to fuel cell technology, as consumer of hydrogen in the hydrogen era, hydrogen production, storage, supply and transfer technologies will also be among the main components of this era's energy structure. Hydrogen is a harmless fuel, which can be produced from crude oil in refineries and is the cheapest fuel in Iran [27].

Given the special status of fuel cell systems, as a leading technology in the realization of the hydrogen era, some studies have already been made by Iran's Renewable Energy Organization, as a representative of the Ministry of Energy, with cooperation of the Ministry of Science, Research and Technology, Ministry of Defense, Ministry of Petroleum, Ministry of Industries and Mines, Presidential Technology Cooperation Office and other stakeholders. Such studies have led to the development of “National Strategy Document of Fuel Cell Technology Development that outlines the activities and goals 20-year Development Vision of the country. The document was approved by assembly on July 2004 [28]. Table 10 shows Iran's fuel cell and hydrogen projects specification.

7. Nongovernmental renewable power plant projects

Due to the necessity of renewable energy application, in Iran, and the requirement to fulfill Article 44 of the Islamic Republic of Iran's Constitution, Iran's Renewable Energy Organization has set participation and investment by nongovernmental sectors as one of its major missions.. Private sectors have already signed contracts to build more than 600 MW of biomass systems and 500 MW of new wind energy developments. Table 11 represents the specifications of nongovernmental renewable power plant projects in 2010. Based on the reports by Iran's Renewable Energy Organization, private sector has already submitted a proposal to generate 3000 MW of electricity.

8. Conclusion and recommendations

The development trends in Iran show that in 20 years, renewable energies will supply 5% of Iran's demand for electricity energy. To

Table 8
Specification of biomass and biogas projects ministry energy of Iran [6,11,14].

Project name	Technology	Region	Start	Utilize	Percentage of progress until 2010	Capacity of project (kW)	Lifespan (year)
Manufacture of vanadium energy storage system (Single-cell)	Energy reservation	Alborz, Taleghan	2002	2005	100	0.01	> 20
Manufacture of semi-industrial stack Vanadium redox battery	Energy reservation	Alborz, Taleghan	2005	2008	100	1	> 20
5 Survey of biomass resource potential in the country	Survey potential	All over the country	1998	2000	100	–	–
Feasibility study for installing of biomass power plant	Survey potential-land fill	Fars, Shiraz	2004	2005	100	1060[a]	13
		Khorasan, Mashhad	2004	2005	100	650[b]	13
Construction biomass power plant in Shiraz	Land fill	Fars	2009	2009	100	1200	–
Construction biomass power plant in Mashhad	Land fill	Khorasan	2009	2009	100	660	–
Feasibility study for biomass	Survey potential (Survey potential)	All over the country	2006	2011[c]	75	10,000	> 20
Potential biomass resource assessment [d]	Survey potential	All over the country	2005	2011[c]	46	–	–
Feasibility study for manufacturing of Biogas in Saveh	Feasibility study	Markazi	2007	2011[d]	88	600	–
Pilot construction for biodiesel production	Feasibility study, design & manufacturing	Markazi	2009	2010	100	70(Lit/h)	10

[a] According to potential evaluations conducted, installable capacity at the urban solid waste disposal site of Shiraz equals 1060 kW. However, considering the position and specifications of waste disposal during past years, the current utilization capacity of the disposal site of the city (Shiraz) is 450 kW.
[b] With regard to the equipment installed, the real rate of electrical energy production from the solid waste disposal site of the city of Mashhad is approximately 654 MWh per month. Of course, the obtainable rate of energy will be considerably increased by constructing of disposal site and installation of complete equipment.
[c] Due to shortage of required funds in the Fourth Development Program and a change in service description, the termination date of this project has been extended.
[d] Source: Water and wastewater engineering company [24].

Table 9
Iran's production capacity and domestic consumption of electricity from biogas power plant [6,14].

Region	Total nominal capacity (MW)	Practical capacity (MW)	Gross electricity generation (GWh)	Domestic consumption
Shiraz biogas power plant	1.2	1.065	2.178	[a]
Mashhad biogas power plant	0.66	0.6	3.789	[a]

[a] Domestic consumption rate has not yet been announced by respective companies.

Table 10
Specification of Full cell and Hydrogen projects of Ministry energy of Iran [6,11].

Project name	Technology	Region	Start	Utilize	Percentage of progress until 2010	Capacity of project(kW)	Lifespan (year)
Peak—shaving with fuel cell	SPE	Tehran	2003	2003	100	–	–
Buying of fuel cell (2.1 kW)	Fuel cell	Alborz, Taleghan	2005	2005	100	1.2	10
Hydrogen and fuel cell pilot	(1)	Taleghan	1996	2005	100	–	20
Thermoplastic bipolar plate production for Polymer fuel cell	Manufacturing of fuel cell components	-	2006	2007	100	–	–
Purchase, installation and operation of 25 kW fuel cell polymer and Accessories	Fuel cell	Alborz, Taleghan	2006	2007	100	25	10
Feasibility, designing and manufacturing single cell of Solid Oxide Fuel Cell	Energy reservation	Taleghan	2005	2007	100	1	> 20
Fuel cell committee	(2)	All over the country	2002	(3)	(4)	–	Promotional research
Purchase, installation and commissioning of water 30 normal electrolysis system (m^3/h)	Water electrolysis	Alborz, Taleghan	2007	2009	100[(5)]	30Nm^3/hr	20
Semi-industrial scale pilot projects in hydrogen technology	(6)	Alborz, Taleghan	1996	2013	65	200	20
Design and manufacturing of (5 kW) polymer fuel cell with the technology knowledge purpose	Fuel cell	Isfahan	2006	2010	100	5	10
Feasibility study for manufacturing single- cell of Solid Oxide Fuel Cell	Fuel cell	Tehran	2007	2010	100	-	10

(1) Production, condensation, storage and supply of hydrogen and photovoltaic system.
(2) This committee has conducted follow-up of ratification of the national strategy document of fuel cell technology and activities related to the secretariat and also updating the website and printing bulletins, in 2005, 2006 and 2007.
(3) The formulated operational schedule will be performed in a 15-year period (three five-year schedules) since the time of document ratification.
(4) The activities related to fuel cell strategic committee are unceasing.
(5) Production, condensation, storage and supply of hydrogen.
(6) Condensation project is stopped due to untimely and insufficient allocation of budget.

Table 11
Specification of renewable energy power plant projects in 2010, Non-governmental [14].

Power plant construction phase			
Company	Proposed capacity (MW)	Power plant location	Region (Province)
Wind power plants			
Qaem power co. (phase 1)	100	Jarandagh	Qazvin
Qaem power co. (phase 2)	100	Binalud	Razavi Khorasan
Royan wind power plant	100	Binalud	Razavi Khorasan
Arg-jam wind power plant	9	Rudbar	Gilan
Sustainable development Co. (phase 1)	20	Bam Siahpush	Qazvin
Fajr sadid nahbandan	10	Nahbandan	South Khorasan
Shahd-e jonoob Chabahar Free Trade-Industrial Zone	10	Chabahar	Sistan and Baluchestan
Tiz bad niroo	100	Khvaf	Razavi Khorasan
ABAN wind turbine Co.	30	Takestan	Qazvin
Matin taam energy development co.	100	Manjil	Gilan
Niroo investment Co.	10	Dashli ghala	North Khorasan
Arian mahbad gostar (mahtab gostar)	123	Siahpush	Qazvin
Total wind power plants	**579**		
Biomass power plants			
Fanavaran energy pak Asia	12	Sari	Sari
Total biomass power plants	**12**		
Solar power plants			
Sazan electronic industry	10	Semnan	Semnan
Total solar power plants	**10**		
Total	601		

attain this objective, governmental approvals regarding the development of new energies should be noted and performed. Accordingly, the following operational steps are recommended to move toward sustainable future and away from environmental issues:

(1) Attention to cultural and educational issues related to macro energy planning for community awareness about environmental issues.
(2) The necessity to use renewable energy to achieve a clean and sustainable society.
(3) The share of new energies should be determined in the country's energy basket, and plans should be devised for its realization.
(4) Required resources to purchase electricity generated from renewable energies should be appropriately realized. For this purpose, the following options should specifically be considered:
    (a) Allocation of a part of public resources in the annual budget to guarantee purchase of electricity generated from renewable energy resources.
    (b) Determination of a percentage of the consumed electricity of subscribers (e.g. 1%) and calculation of its price and its inclusion in the subscriber's bill using guaranteed prices of renewable energies.
    (c) Formulation of green electricity tariff and calculation of the electricity price of all governmental institutions, using this tariff and advertising its optional acceptance by environment supporter subscribers, with the support of environment supporter NGOs, depositing of the resources resulting from high consumptions directly to an account for renewable energy development.
5. Allocation of a part of construction expenditure of renewable energy power plants from the government's gratuitous assistance and allocation of a certain share to investigate reduction rate of construction expenditures of these power plants.

Acknowledgments

The authors would like to thank Ministry of Energy, Majlis (Iranian parliament) Research Center and especially renewable energies organization of Iran (SUNA) for providing the data for this research.

References

[1] International Energy Agency (IEA), Key world energy statistics, 2011. Available from: at:⟨http://www.iea.org/textbase/nppdf/free/2011.pdf⟩.
[2] World Consumption of Primary Energy By Energy Type and Selected Country Groups, 2008. Microsoft Excel file format. Available from: ⟨http://www.eia.doe.gov/pub/international/iealf/table18.xls⟩. [accessed 10.09.10].
[3] Arent DJ, Wise A, Gelman R. The status and prospects of renewable energy for combating global warming. Energy Economics 2011;33:584–93.
[4] The Energy Report, 100% Renewable Energy By 2050. WWF The Energy Report, 2011, p.104. Available from: ⟨http://wwf.panda.org/what_we_do/footprint/climate_carbon_energy/energy_solutions/renewable_energy/sustainable_energy_report/⟩.
[5] International Energy Agency (IEA), Energy statistics and balances of Non-OECD countries 2011. Available from: ⟨http://www.iea.org/stats/index.asp⟩.
[6] Ministry of Energy of Iran. Available from: ⟨http://www.moe.org.ir/Homepage.aspx?site=DouranPortal&tabid=1&lang=fa-IR⟩. [accessed 01.04.11]. in Persian].
[7] Kaldellis JK, Zafirakis D. The wind energy (r)evolution: a short review of a long history. Renewable Energy 2011;36:1887–901.
[8] Energy Efficiency and Renewable Energy. US Department of Energy. Available from: ⟨http://energy.gov/⟩.
[9] Pennsylvania Wind Working Groups. Available from: ⟨http://www.pawindenergynow.org/wind/benefits.html⟩.
[10] Dimitris Al. Katsaprakakis. A review of the environmental and human impacts from wind parks. a case study for the Prefecture of Lasithi, Crete. Renewable and Sustainable Energy Reviews 2012;15:2850–63.
[11] Deputy for Executive and Technical, Iran's renewable energy organization (Suna). Available from: ⟨http://www.suna.org.ir/en/executive⟩.
[12] Ministry of Energy. Iranian energy balance sheet, yearbook 1389, Tehran, 2011. Available from: ⟨www.energyconf.ir/pdf/3.pdf⟩. [in Persian].
[13] ⟨www.suna.org.ir⟩.
[14] Energy, Industry & Mine Group, Iranian parliament research center, 2012. Available from: ⟨http://rc.majlis.ir/en/department/mine_industry_energy_department⟩.
[15] Najafi Gh Ghobadian B. LLK1694-wind energy resources and development in Iran. Renewable and Sustainable Energy Reviews 2011;15:2719–28.
[16] Solangib KH, Islam MR, Saidur R, Rahim NA, Fayaz H. A review on global solar energy policy. Renewable and Sustainable Energy Reviews 2011;15:2149–2163.
[17] International Energy Agency, 2011. Available from: ⟨http://www.iea.org/Textbase/npsum/solar2011SUM.pdf⟩. [accessed 03.12.11].
[18] Fadai D. Analyzing the causes of non-development of renewable energy-related industries in Iran. Renewable and Sustainable Energy Reviews 2011;15:2690–5.
[19] Maps of Global horizontal irradiation, SolarGIS © 2013 GeoModel Solar s.r.o. Available from: ⟨http://solargis.info/doc/71⟩.
[20] Yousefi H, Noorollahi Y, Ehara S, Itoi R, Yousefi A, Fujimitsu Y, et al. Developing the geothermal resources map of Iran. Geothermics 2010;39:140–51.
[21] Najafi Gh, Ghobadian B. Geothermal resources in Iran: the sustainable future. Renewable and Sustainable Energy Reviews 2011;15:3946–51.
[22] Najafi Gh, Ghobadian B. Geothermal resources in Iran: the sustainable future. Renewable and Sustainable Energy Reviews 2011;15:3946–51.

[23] Kazem HA. Renewable energy in Oman: status and future prospects. Renewable and Sustainable Energy Reviews 2011;15:3465–9.
[24] Iran's water and wastewater engineering company. Available from: 〈http://www.nww.co.ir/〉.
[25] Hamzeh Y, Ashori A, Mirzaei B, Abdulkhani A, Molaei M. Current and potential capabilities of biomass for green energy in Iran. Renewable and Sustainable Energy Reviews 2011;15:4934–8.
[26] Jefferson Lab, the Element Hydrogen. Available from: 〈http://education.jlab.org/itselemental/ele001.html〉.
[27] Ghobadian B, Najafi Gh, Rahimi H, Yusaf TF. Future of renewable energies in Iran. Renewable and Sustainable Energy Reviews 2009;13:689–695.
[28] Introduction to hydrogen and fuel cell Department. Available from: 〈http://www.suna.org.ir/executive-hydrogenandfuelcell-hydandfuel-en.html〉.